ENVIRONMENTAL CHARACTERISTICS OF SMART GROWTH NEIGHBORHOODS

Phase II: Two Nashville Neighborhoods

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NRDC
THE EARTH'S BEST DEFENSE

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EXECUTIVE SUMMARY

Sprawling land development, characterized by low-density, single-use subdivisions at and beyond the fringe of metropolitan regions, is known to cause a range of environmental problems, from consumption of open space to polluted water runoff to energy waste and air pollution from high rates of automobile dependence. There is a growing body of research indicating that these problems can be ameliorated by building neighborhoods in a different way, using infill or close-in sites with walkable, compact street and lot design integrated with or closer to jobs, shopping, and community amenities.

An exploratory case study conducted for the Natural Resources Defense Council (NRDC), in cooperation with the United States Environmental Protection Agency (EPA) and published in 2000, compared three residential projects in Sacramento, California, and suggested that the environmental benefits of smart growth are real and can be measured. This new study (also conducted for NRDC in cooperation with EPA) continues that research by comparing two neighborhoods in Nashville, Tennessee, and suggests that the combination of better transportation accessibility and a modest increase in land-use density can produce measurable benefits even when both sites are automobile-oriented and suburban in character.

Prior to this research, most studies on this subject had evaluated proposed or conceptual projects, not built and occupied neighborhoods. This new case study is one of the first to examine developed transportation analysis zones (TAZs), with different locational and neighborhood design characteristics, in a manner that allows comparison of both their land-use and transportation characteristics. As with the earlier Sacramento study, few firm or general conclusions can be drawn from a limited case study, but the Nashville findings are similarly consistent with the precepts of smart growth. Taken together, the two case studies suggest that additional, more comprehensive research on additional sites could prove fruitful in confirming that new development can be successfully designed and located to perform more efficiently than conventional development in terms of several environmental indicators, including land consumption, water use, stormwater pollution, and energy use and air pollution from residents' travel patterns.

The Nashville study included two sites: 1) a fully built-out "inner ring" suburban neighborhood named Hillsboro; and 2) an "outer ring" suburban area still undergoing development named Antioch. The Hillsboro study site is located approximately three miles from downtown Nashville. Although its location might be considered "urban" in the context of the greater Nashville region as a whole, the site is suburban in physical character, with its single-family homes on large lots and a high degree of automobile dependence. It is best thought of as an inner suburb. The Antioch site is an outer suburb, ten miles from downtown and with a lower average density than Hillsboro. Although some moderately sized lots are being introduced into Antioch, many of its older single-family homes occupy large lots and it is also characterized by a high degree of automobile dependence. Hillsboro can be said to be somewhat "smarter" than Antioch because of its closer-in location and higher average density. Because both sites were defined as TAZs that have been the subject of a recent travel survey, the Nashville sites

allowed a much more reliable set of findings with regard to transportation than did the Sacramento sites.

In fact, Hillsboro outperformed Antioch on a number of per-capita environmental indicators, including land consumption, water consumption, air pollutant emissions, greenhouse gas emissions, and stormwater runoff and associated nonpoint source water pollution. In particular, Hillsboro occupies only some two-thirds as much land per capita as does Antioch; its residents consume around 13 percent less water per capita; Hillsboro's vehicles emit some seven percent less air pollution and around 25 percent less carbon dioxide, the most significant greenhouse gas, per capita; and its average annual rates of stormwater runoff and associated water pollution per capita are only about half those of Antioch. Hillsboro's lower air pollution and greenhouse gas emissions are due to significantly lower rates of vehicle travel; its lower rates of stormwater runoff and water pollution are due to a lower rate of paved impervious surfaces for its street network.

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CHAPTER 1

INTRODUCTION

PURPOSE

The purpose of this study is to compare the land-use and transportation characteristics of a matched pair of neighborhoods in the same region, each with different design and accessibility characteristics, and their resulting performance on a range of environmental indicators. The objective is to identify relationships between regional growth, community design, and environmental quality, and to use this information to help inform community and regional planning practices. The study, conducted in greater Nashville Tennessee, builds upon a previous exploratory study conducted in Sacramento, California.[1]

BACKGROUND

The study was commissioned by the Natural Resources Defense Council (NRDC) in cooperation with the U.S. Environmental Protection Agency (EPA). NRDC and the EPA are interested in identifying the environmental benefits of "smart growth" policies, and one method being used is a series of case studies comparing matched pairs of study sites according to their:

Design: This is the internal character of an area, including its land-use mix and density, and its capabilities for multi-modal travel both internally and externally. These characteristics affect a neighborhood's environmental impact in its immediate vicinity.

Accessibility: This is an area's accessibility to the surrounding region measured in travel time to all other destinations in the region. This characteristic affects the environmental burden a neighborhood places on the region from travel to major destinations such as employment and shopping.

Previous studies have found that both design and accessibility can have significant impacts on the environmental performance of neighborhoods.

In particular, the case study in Sacramento that preceded this one focused on Metro Square, a development of single-family, detached homes built one mile from

[1] Natural Resources Defense Council, *Environmental Characteristics of Smart Growth Neighborhoods: An Exploratory Case Study* (October 2000). See www.nrdc.org/cities/smartgrowth.

Sacramento's city center, with compact lots situated around common green space, and conventional grid-pattern streets. Compared to two conventional outer suburban developments with the same number of single-family homes, Metro Square was found to consume only roughly one-quarter as much land and contain less paved surface per household and per capita than the conventional developments, reducing surface water runoff. In addition, while the Sacramento study's analysis of residents' travel behavior was not sufficiently detailed to reach firm conclusions, the preliminary evidence suggested that the location and features of Metro Square may well also make a difference in reducing driving and attendant motor vehicle pollution.

CHAPTER 2

SITE SELECTION

Site selection for the study occurred in two stages: 1) selection of a study region, and 2) selection of neighborhood study areas within the region.

Criteria for selecting a study region included: presence of a single agency with consolidated responsibilities for both transportation and land-use planning to facilitate data collection and local coordination; availability of a parcel-level GIS database to characterize land-use conditions; and availability of a relatively recent travel behavior survey to characterize travel behavior. A brief survey of metropolitan areas was conducted and Nashville, Tennessee was selected because it has a consolidated city-county government with a planning department responsible for both land-use and transportation planning; and it has a detailed GIS database and a travel behavior survey that was completed in 1998. It was also seen as an advantage that the Nashville metropolitan area is geographically and culturally distinct from the Sacramento region and thus would add richness to the cumulative research findings on the attributes being studied.

Aside from accessibility and design considerations, criteria for selecting the two study areas within the Nashville region were similarity in household size, auto ownership, and trip making rates (current household income data was not available). The objective was to control for household socioeconomics at both study sites since those factors heavily influence both housing choice and travel behavior; and, by doing so, to reveal land use and travel demand differences that may be due to differences in design and/or accessibility.

Using these criteria, and local MPO traffic analysis zones (TAZ) as the equivalent of neighborhoods, a somewhat more "urban" site was selected in the Hillsboro area near central Nashville (TAZ 97) and an outer suburban site was identified in the Antioch area (TAZ 216). The selection of TAZs with recent travel behavior surveys as the study sites allowed for a much more accurate analysis of travel characteristics for the Nashville study sites than was possible in the Sacramento study.

It should be noted, however, that neither site possesses many of the characteristics generally thought of as urban, such as high levels of density, mixed uses, good pedestrian amenities, and public transit service. Both are suburban in style, with Hillsboro differing from Antioch most notably in its more central location, somewhat higher density, and grid road network. This profile of similarities and differences allows the study findings to reveal something of the potential differences in environmental performance between inner- and outer-suburban areas in a heavily automobile-dependent region.

CHAPTER 3

STUDY AREAS

The regional locations of the two study TAZs are shown in Figure 1 and their major characteristics are summarized in Table 1. Profiles of the two areas are as follows:

HILLSBORO (TAZ 97)

This is a 427-acre TAZ located approximately three miles from downtown Nashville. It contains 824 households with a total population of 1,757 persons. The area is shown in Figure 2 using recent aerial photography; in Figure 3 according to existing land-use; and in Figure 4 with major transportation features. It is a predominantly single-family residential area originally developed during the 1950s and 60s. It constitutes a form of older or "inner ring" neighborhood that has become geographically more urban despite its suburban-style built environment. It is completely built-out, and its only non-residential uses are churches. Parks, schools, shopping, and other amenities are located in adjacent neighborhoods. The TAZ does have a significant multi-family share of total dwellings. Photographs of the area appear in Appendix A.

Table 1. Study Area and Household Characteristics, Source, Nashville Area MPO

	Urban-Hillsboro (TAZ 97)	Suburban-Antioch (TAZ 216)
Acres	427	2,775
Population	1,757	6,816
Households	824	3,069
Persons/household	2.13	2.22
Autos/household	1.98	1.88
Daily trips/household	7.62	7.60

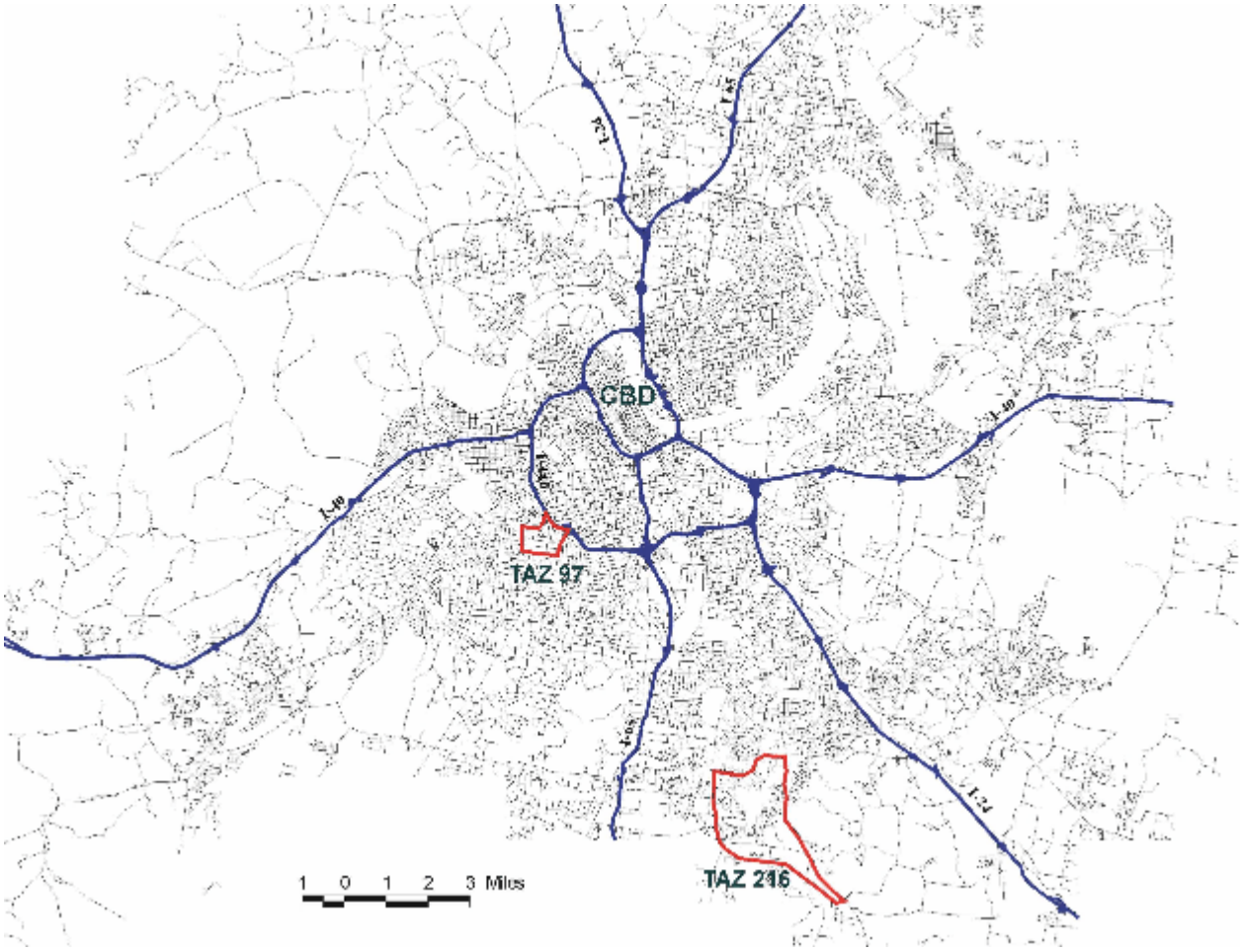

Figure 1. Regional Location of Study TAZs

Figure 2. Hillsboro Aerial Photo

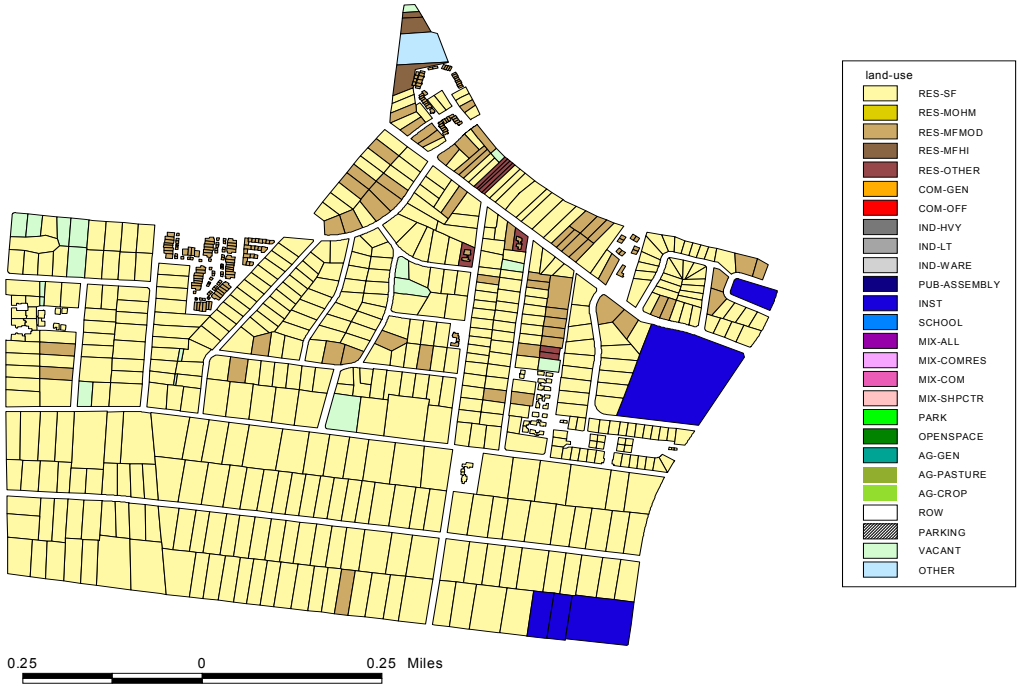

Figure 3. Hillsboro Existing Land Use

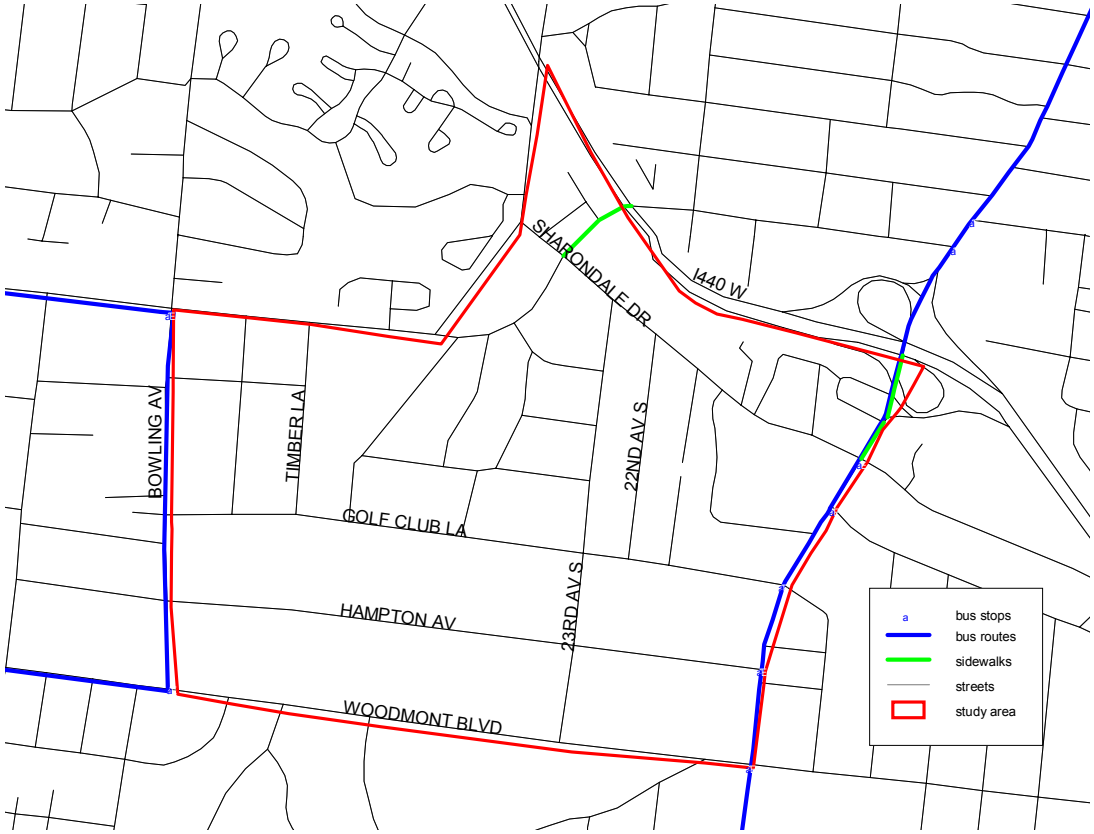

Figure 4. Hillsboro Transportation Features

ANTIOCH (TAZ 216)

This is a 2,775-acre TAZ located approximately ten miles from downtown Nashville. It contains 3,069 households with a total population of 6,816 persons. The area is shown using recent aerial photography in Figure 5; by existing land-use in Figure 6; and according to major transportation features in Figure 7. It is a predominantly single-family area, with a notable amount of multi-family residential and limited strip commercial uses. The area supported agricultural uses until suburbanization began during the 1970s and 80s. Residential development steadily increased through the 1990s, with about half of the area currently built-out. Its development pattern is constrained by hilly topography that does not apply to the Hillsboro TAZ. Its larger acreage and population in comparison to the Hillsboro TAZ was considered acceptable for the study because of indicator results being expressed on a per capita basis (although this TAZ is especially large in comparison to that for Hillsboro, larger TAZs in outer suburban areas are unavoidable because regional transportation models increase TAZ size as population density decreases). Photographs of the area appear in Appendix A.

ANALYSIS METHODS

The study utilized two primary methods of analyzing the TAZs. First, the MPO's regional transportation demand model and travel survey provided estimates of household vehicle use for the TAZs. Second, local land-use data was modeled in INDEX software to characterize land-use conditions in the TAZs, and to estimate environmental impacts of both land-use and transportation activities.

Figure 5. Antioch Aerial Photo

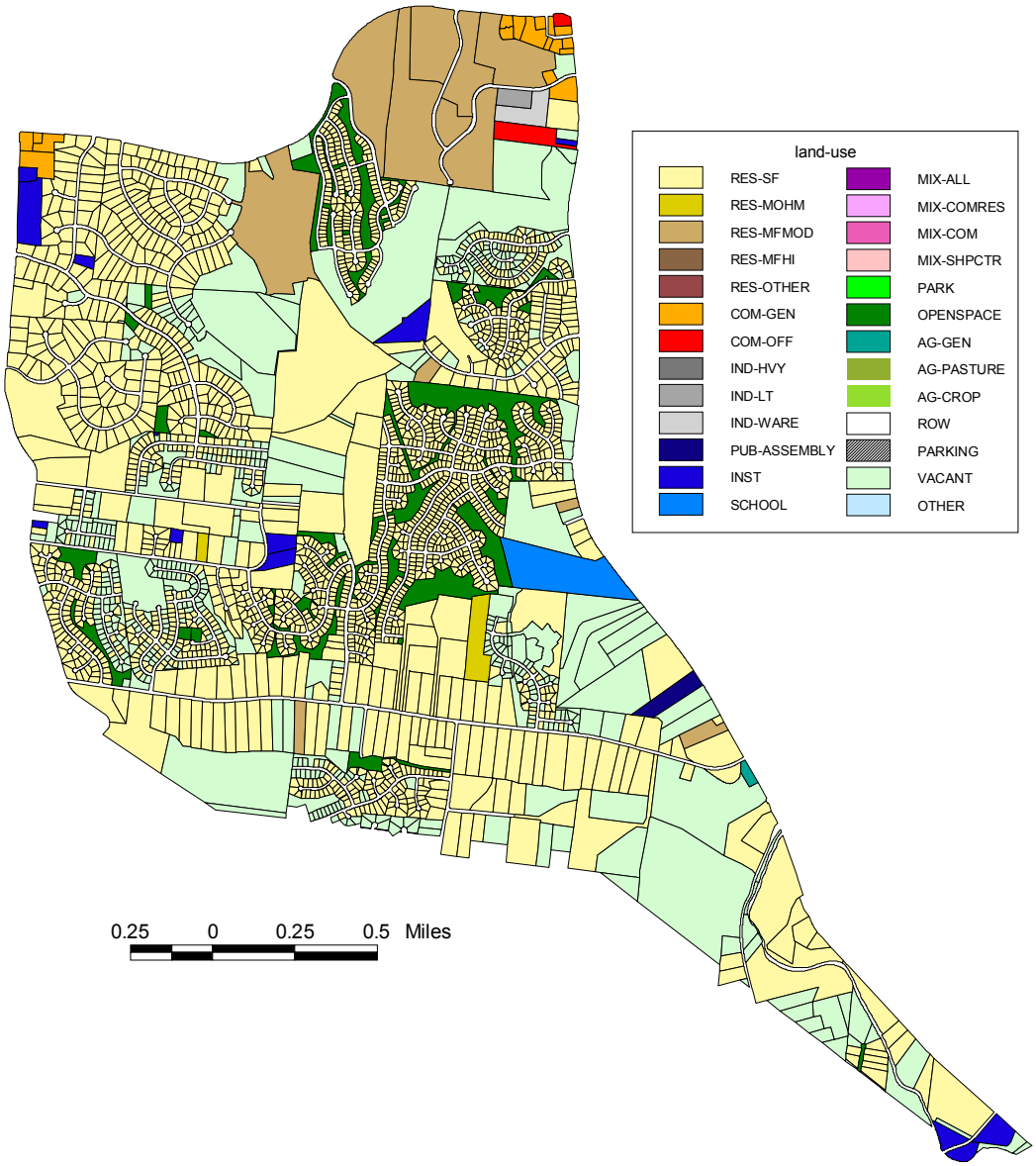

Figure 6. Antioch Existing Land Use

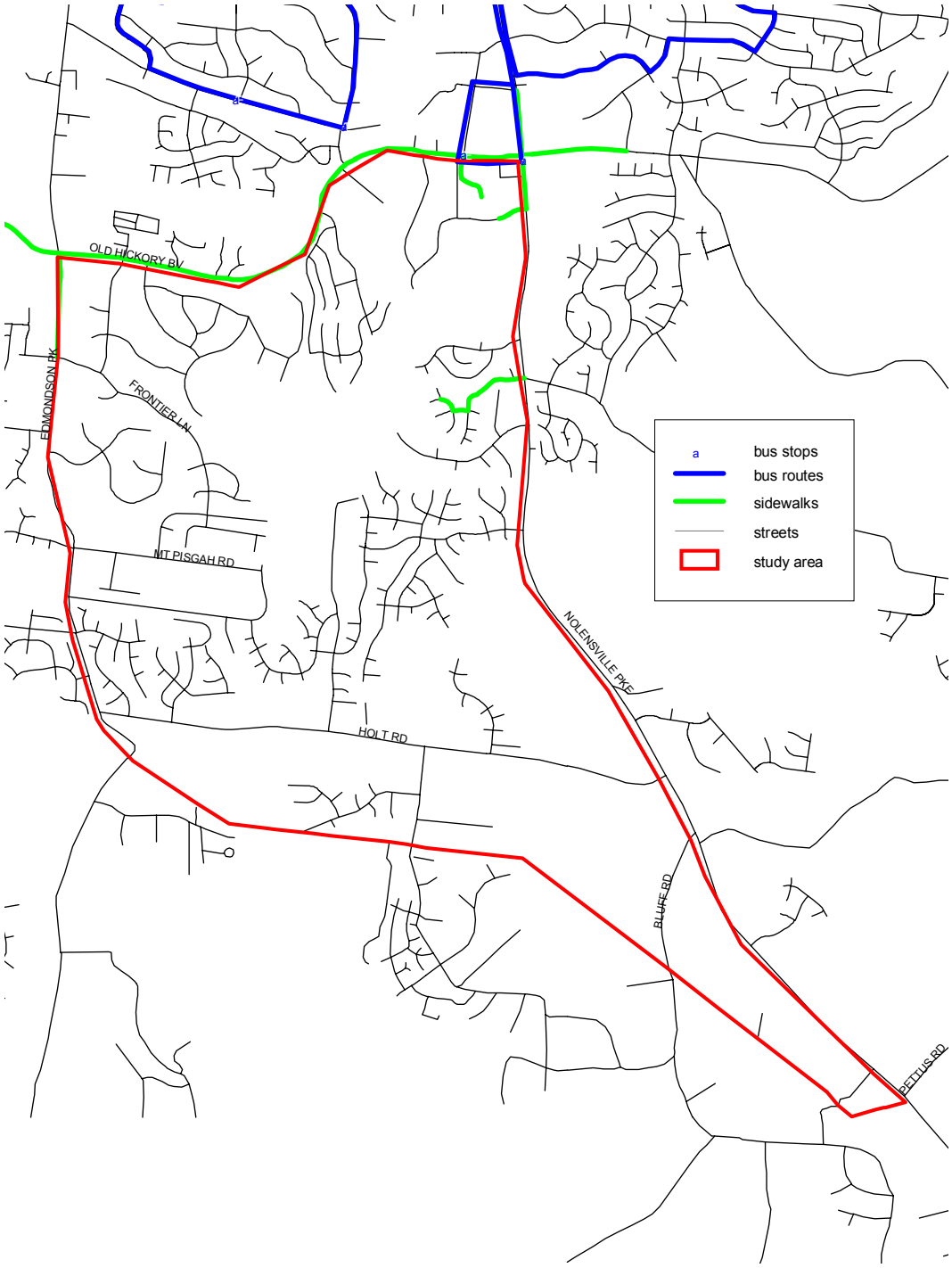

Figure 7. Antioch Transportation Features

CHAPTER 4

RESULTS

Indicator scores for the study areas are given in Table 2. The TAZs turn out to be a matched pair whose biggest environmental performance differences are:

Regional accessibility. The suburban Antioch TAZ is seven miles farther from the Nashville CBD than the Hillsboro TAZ, and the dominance of the Nashville CBD as an employment center as well as Antioch's greater distance from other destinations results in per capita vehicle miles traveled for Antioch being about 30 percent higher than Hillsboro. Consequently, air pollutant and greenhouse gas emissions per capita are significantly higher for Antioch.

Design. Antioch's scores for street networks and stormwater were less favorable than Hillsboro's. This appears to be due to a combination of uncoordinated design among individual subdivision projects, and hilly topography that necessitates longer curvilinear street designs, and overall lower density. This, in turn, creates greater amounts of per capita imperviousness and runoff.

Despite its shortcomings at present, the suburban Antioch TAZ still has an opportunity for improving its ultimate build-out scores through design improvements in future projects. As with many other regions in the country, Nashville is beginning to see the effects of "new urbanist" and "smart growth" policies and designs on the ground. In fact, construction of a higher density, mixed-use subdivision (Lenox Village) was noted during the study immediately adjacent to the Antioch TAZ boundary. It is this kind of trend that will affect the Antioch TAZ's ultimate environmental performance.

Indicator scores from Table 3 are reviewed below by major characteristics:

Table 2. Land Division (grain)

INDICATOR	UNITS	HILLSBORO	ANTIOCH
Block Size	(acres)	13.48	132.01
Parcel Size	(sq ft)	19423	41207
Parking Lot Size	(acres)	1.12	1.24

Hillsboro block and parcel sizes are relatively large for urban conditions, due to the area's original development as a suburban neighborhood. Antioch's very large block and parcel sizes are due to its rural roots and partially developed character. Its newer residential projects still have relatively large blocks, but new lots are being platted at urban densities, e.g. 8,000 sq.ft. Parking lot size in both areas are typical neighborhood-scale.

Table 3 Indicator Scores

			STUDY AREA	
ELEMENT	INDICATOR	UNITS	HILLSBORO	ANTIOCH
Demographics	Study Area Population	(residents)	1973	6722
Land-Use	Block Size	(acres)	13.48	132.01
	Parcel Size	(sq ft)	19423	41207
	Parking Lot Size	(acres)	1.12	1.24
	Use Mix	(0 to 1 index)	0.14	0.11
	Use Balance	(0 to 1 index)	0.18	0.30
	Neighborhood Completeness	(% key uses w/i ½ mi. walk)	5	43
Housing	Population Density	(residents/net acre)	6.19	4.14
	Residential Footprint	(net acres/1000 residents)	161.60	241.52
	Single-Family Parcel Size	(sq ft)	24915	28064
	Single-Family Dwelling Density	(SF DU/net acre)	1.82	1.48
	Multi-Family Dwelling Density	(MF DU/net acre)	12.46	8.43
	Single-Family Dwelling Share	(%)	59	59
	Multi-Family Dwelling Share	(%)	40	41
	Amenities Proximity	(ft to closest grocery)	5925	7515
	Bus Transit Proximity to Housing	(ft to closest stop)	2227	8045
	Water Consumption	(gal/day/capita)	96.05	110.95
Employment	Jobs Per Capita	(jobs/resident)	0.03	0.06
	Jobs to Housing Balance	(jobs/DU)	0.07	0.23
	Employment Density	(emps/net acre)	3.88	7.52
	Commercial Building Density	(ratio)	0.00	0.13
	Bus Transit Proximity to Employment	(ft to closest stop)	232	3633
	Pedestrian Setback	(avg. non-res setback ft)	118	87
Recreation	Park Space Supply	(acres/1000 res.)	0	3.46
	Park Proximity	(ft to closest)	5756	7456
Environment	Air Pollutant Emissions	(lbs/capita/year)	248	267
	Greenhouse Gas Emissions	(lbs/capita/year)	8322	11023
	Open Space Share	(%)	0	4.3
	Open Space Connectivity	(0 to 1 index)	N/A	0.33
	Stormwater Runoff	(cu. ft/yr/capita)	2511	4948
	Nonpoint Pollution	(kg/yr/capita)	3.3	7.0
	Imperviousness	(acres/capita)	0.11	0.17

Table 3 Indicator Scores (continued)

Travel	Internal Street Connectivity	(intersections/node ratio)	0.94	0.52
	External Street Connectivity	(ft between access pts)	865	1766
	Street Network Density	(miles/sq. mi.)	13.64	8.38
	Street Network Extent	(miles/1000 residents)	4.61	5.40
	Transit-Adjacent Residential Density	(DU/net acre)	2.40	5.89
	Transit-Oriented Residential Density	(DU/net acre)	1.94	5.90
	Transit-Adjacent Employment Density	(emps/net acre)	3.37	3.35
	Transit-Oriented Employment Density	(emps/net acre)	3.37	3.35
	Transit Service Coverage	(stops/sq mi)	7	1
	Transit Service Density	(veh-mi/day/acre)	0.44	0
	Pedestrian Network Coverage	(% of streets)	3	2
	Sidewalk Width	(feet)	3	4
	Pedestrian Crossing Distance	(feet)	28	29
	Pedestrian Route Directness	(route ft/direct ft ratio)	1.51	1.52
	Bicycle Network Coverage	(% of streets)	0	0
	Regional Accessibility	(min. to all other TAZs)	28.62	32.47
	Vehicle Miles Traveled	(veh-mi/day/capita)	22.8	30.2
	Vehicle Trips	(veh-trips/day/capita)	3.5	3.4

Table 4. Land-Use

INDICATOR	UNITS	HILLSBORO	ANTIOCH
Use Mix	(0 to 1 index of grid dissim)	0.14	0.11
Use Balance	(0 to 1 index of proportional area)	0.18	0.30
Neighborhood Completeness	(% key uses w/i ½ mi. walk)	5	43

Use mix is low for both areas because of their dominant residential character. Use balance appears higher in Antioch because of its comparatively larger land areas devoted to multi-family residential and commercial uses. Antioch also scored significantly higher on neighborhood completeness because more of its developed portion is located at its northern edge adjacent to its commercial strips. It should be noted, however, that these differences occur in comparing two TAZs that are strikingly dissimilar in size. Antioch has over three times the population and seven times the area of Hillsboro. Because the areas adjacent to the smaller Hillsboro TAZ supply multi-family residential and commercial uses along with neighborhood amenities – features that lie within the larger

Antioch TAZ – it is possible that Hillsboro would have scored higher on these scales if the TAZ were expanded to include a similar population or area to Antioch. This illustrates a limitation of using TAZs as boundaries for comparative land-use/transportation studies: TAZ size tends to increase with distance from a region's central city to account for typically decreasing population densities, although as in this case the increase in size can be disproportionate to the decrease in density. In this study, it was considered more important to control for household size, auto ownership, and trip-making between the two sites, which ultimately determined TAZ selection; dissimilarity in TAZ size is largely mitigated by the expression of indicator results on a per capita basis.

Table 5. Residential Density

INDICATOR	UNITS	HILLSBORO	ANTIOCH
Population Density	(residents/net acre)	6.19	4.14
Residential Footprint	(net acres/1000 residents)	161.60	241.52
Single-Family Parcel Size	(sq ft)	24915	28064
Single-Family Dwelling Density	(SF DU/net acre)	1.82	1.48
Multi-Family Dwelling Density	(MF DU/net acre)	12.46	8.43

Population and housing densities are typical for the region in both cases. Antioch's results are influenced partly by a large number of very large single-family parcels that date from the 1950s and 60s. As noted earlier, current market forces have reduced new residential lots to more urban levels, e.g. 8,000 sq.ft. In addition, Antioch's multi-family dwellings are not as compactly designed as Hillsboro's. Although their locations are dissimilar, both neighborhoods may properly be characterized as typically suburban with respect to internal design. Overall, Hillsboro's residential footprint (land consumption per capita) is only about two-thirds that of Antioch.

Table 6. Housing Types

INDICATOR	UNITS	HILLSBORO	ANTIOCH
Single-Family Dwelling Share	(%)	60	59
Multi-Family Dwelling Share	(%)	40	41

Both areas have virtually identical share splits between single-family and multi-family (which is also another socioeconomic control factor for comparing the two neighborhoods).

Table 7. Housing Accessibility

INDICATOR	UNITS	HILLSBORO	ANTIOCH
Amenities Proximity to Housing	(ft to closest grocery)	5925	7515
Bus Transit Proximity to Housing	(ft to closest stop)	2227	8045

Neither area has favorable walking distances from housing to shopping or transit, except for Hillsboro's marginally-acceptable bus stop distance.

Table 8. Employment

INDICATOR	UNITS	HILLSBORO	ANTIOCH
Jobs Per Capita	(jobs/resident)	0.03	0.06
Jobs to Housing Balance	(jobs/DU)	0.07	0.23

Neither area has significant employment within its boundaries. Hillsboro's is limited to a small number of churches, and Antioch's is limited to churches and its two retail commercial nodes. It is possible that Hillsboro's score would have been higher on these indicators if inner region TAZs were as large as Antioch, or if multiple inner TAZs could have been aggregated without losing the household control factor between the two sites (which was not possible in the case of Nashville).

Table 9. Nonresidential Land Use

INDICATOR	UNITS	HILLSBORO	ANTIOCH
Employment Density	(emps/ net acre)	3.88	7.52
Commercial Building Density	(ratio)	0.00	0.13
Bus Transit Proximity to Employment	(ft to closest stop)	232	3633
Pedestrian Setback	(avg. non-res setback ft)	118	87

The employment and commercial activity that does exist occurs at relatively low densities in both areas. Hillsboro does enjoy a very favorable transit walk distance to its non-residential establishments. Again, it is possible that Hillsboro's score would have been higher on these indicators if a study area comparable to Antioch had been feasible.

Table 10. Parks & Open Space

INDICATOR	UNITS	HILLSBORO	ANTIOCH
Park Space Supply	(acres/1000 res.)	0	3.46
Park Proximity	(ft to closest)	5756	7456
Open Space Share	(%)	0	4.3
Open Space Connectivity	(0 to 1 index)	N/A	0.33

Hillsboro has no park nor any dedicated open space within the TAZ boundary. The walk distance to the closest park is unfavorably high. Antioch does have a modest amount of park and open space, but at a considerable distance from most homes because of limited street connectivity.

Table 11. Circulation Network

INDICATOR	UNITS	HILLSBORO	ANTIOCH
Internal Street Connectivity	(intersections/node ratio)	0.94	0.52
External Street Connectivity	(ft between access pts)	865	1766
Street Network Density	(miles/sq. mi.)	13.64	8.38
Street Network Extent	(miles/1000 residents)	4.61	5.40

Hillsboro has favorable street network values, including high internal connectivity and relatively easy ingress/egress on its boundaries. Antioch's results are penalized by its partially developed character, and hilly topography that constrains street placement.

Table 12. Transit Environment

INDICATOR	UNITS	HILLSBORO	ANTIOCH
Transit Service Coverage	(stops/sq mi)	7	1
Transit Service Density	(veh-mi/day/acre)	0.44	0
Transit-Oriented Residential Density	(DU/net acre)	1.94	5.90
Transit-Oriented Employment Density	(emps/net acre)	3.37	3.35

The Nashville region has limited transit service generally, and scores in both areas reflect these conditions, although Hillsboro enjoys marginally better service coverage. However, even with service coverage improvements, ridership would be constrained by unfavorably low residential and employment densities.

Table 13. Pedestrian & Bicycle Environment

INDICATOR	UNITS	HILLSBORO	ANTIOCH
Pedestrian Network Coverage	(% of streets)	3	2
Sidewalk Width	(feet)	3	4
Pedestrian Crossing Distance	(feet)	28	29
Pedestrian Route Directness	(route ft/direct ft ratio)	1.51	1.52
Bicycle Network Coverage	(% of streets)	0	0

Pedestrian conditions in both areas are unfavorable on collector and arterial streets. Traffic volumes on local streets are low enough to prevent conflicts with pedestrians walking in travel lanes where shoulders are not available. Newer subdivisions in Antioch are including sidewalks, but these are being constructed without connections to other subdivisions or neighborhood areas. Neither of the TAZs have designated bike routes, but again, local streets are easily used by bicycles because of low traffic volumes and speeds; arterial and collector use appears to be hazardous because of high volume, high speed traffic conditions with very limited shoulders.

Table 14. Household Travel

INDICATOR	UNITS	HILLSBORO	ANTIOCH
Regional Accessibility	(min. to all other TAZs)	28.62	32.47
Vehicle Miles Traveled	(veh-mi/day/capita)	22.8	30.2
Vehicle Trips	(veh-trips/day/capita)	3.5	3.4

The single biggest difference between the two study areas is the greater amount of driving done by Antioch households as a function of their outer suburban regional location in comparison to Hillsboro. Antioch's greater travel distances are due to longer work trips to the Nashville CBD, and marginally longer non-work trips to dispersed suburban schools, shopping, and other destinations. It appears that the greater amount of VMT in Antioch is due to trip distances rather than modal splits, since non-auto mode shares are estimated by the MPO to be equal at both sites.

Table 15. Water & Air

INDICATOR	UNITS	HILLSBORO	ANTIOCH
Water Consumption	(gal/day/capita)	96.05	110.95
Air Pollutant Emissions	(lbs/capita/year)	248	267
Greenhouse Gas Emissions	(lbs/capita/year)	8322	11023

Water consumption is higher in Antioch as a function of its larger parcels and consequent greater irrigation use. Air pollutant and greenhouse gas emissions are higher in Antioch because of higher vehicle miles traveled. Hillsboro residents consume around 13 percent less water and emit around 12 percent less carbon dioxide and 44 percent less carbon dioxide, the most significant greenhouse gas, per capita than do residents of Antioch

Table 16. Stormwater

INDICATOR	UNITS	HILLSBORO	ANTIOCH
Imperviousness	(acres/capita)	0.11	0.17
Stormwater Runoff	(cu. ft/yr/capita)	2511	4948
Nonpoint Pollution	(kg/yr/capita)	3.3	7.0

Development patterns in Antioch are creating more imperviousness per capita, and as a consequence, more stormwater runoff and nonpoint source pollution. This appears to be due to the curvilinear design of street networks necessitated by Antioch's hilly topography, the effect of which is greater street distance, and imperviousness, per capita, as well as by lower overall density. Hillsboro's rates of stormwater runoff and associated pollution are only about half those of Antioch.

USE OF RESULTS

The Nashville results suggest that more centrally located neighborhoods, even if suburban in character, exhibit lower rates of driving and vehicle emissions. The implication is that smart-growth strategies intended to limit growth in automobile dependence and emissions should look first to centrally located sites for infill and redevelopment. They also are consistent with the findings of the previous research in Sacramento that impervious surface and consequent stormwater runoff per capita decrease as density increases, suggesting that smart-growth strategies should continue to seek compact forms of neighborhood development to reduce water pollution